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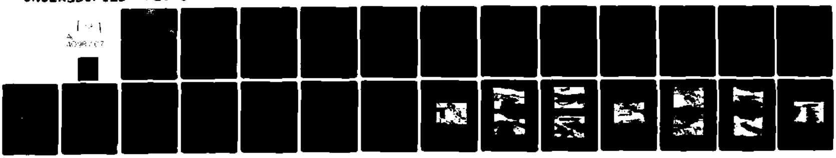

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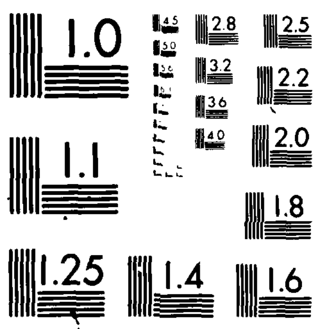

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SECTION 32 PROGRAM. STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION. WORK UNIT 2-EVALUATION OF EXISTING BANK PROTECTION.

FIELD INSPECTION OF THE FISHER RIVER CHANNEL REALIGNMENT PROJECT NEAR LIBBY, MONTANA.

by

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Inspection Report II

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

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SECTION 32 PROGRAM

STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION

WORK UNIT 2 - EVALUATION OF EXISTING BANK PROTECTION

FIELD INSPECTION OF THE FISHER RIVER CHANNEL REALIGNMENT PROJECT NEAR LIBBY, MONTANA

1. The U. S. Army Engineer Waterways Experiment Station (WES) Section 32 Program evaluation team inspected the Fisher River Channel Realignment Project on 8 August 1979. WES personnel participating in the inspection effort were Messrs. E. B. Pickett and N. R. Oswalt, Hydraulics Laboratory; Dr. E. B. Perry, Geotechnical Laboratory; and Messrs. M. P. Keown and E. A. Dardeau, Jr., Environmental Laboratory (EL). The WES team was accompanied during the inspection by Mr. G. W. Ristau, U. S. Army Engineer District, Seattle (NPS) and Mr. T. J. H. Bonde (Libby Dam Project Office, NPS). Fisher River Project was designated as an existing site at the Eighth Section 32 Program Steering Committee meeting on 18 October 1979. As a result, Mr. Keown visited the Libby Dam Project Office on 30 and 31 October 1979 to gather the additional information needed to assemble and write this inspection report; the plates were prepared by Mr. R. M. Russell, Jr. (EL). Special acknowledgment is made to Mr. Bonde, who made available the comprehensive file resources of the Libby Dam Project Office.

2. Fisher River is a left-bank tributary of the Kootenai River at mile 218.2 (Figure 1); this confluence is located 3.5 miles downstream from Libby Dam. Fisher River channel realignment was a direct consequence of the Libby Dam construction project; thus, a brief history of the project is provided as part of this inspection report. Libby Dam is located on the Kootenai River in northwestern Montana 221.7 river miles upstream from its confluence with the Columbia River and 17 river miles above the town of Libby, Montana. The drainage area of the Kootenai River upstream from the damsite covers 8,985 square miles of which 1,325 square miles are in northwestern Montana and 7,660 in southeastern British Columbia. Libby Dam is a multipurpose project constructed as an integral unit of the comprehensive water resource development plan of the Columbia River Basin in the United States and Canada. Preliminary surveys were conducted in the vicinity of the damsite during the period 1948 to 1954 but were discontinued because of the lack of progress in reaching an agreement with Canada that would permit construction of the project. Engineering studies were reactivated in April 1961 after the United States Congress ratified a treaty with Canada. Construction of Libby Dam and Lake Koocanusa was authorized by Public Law 516, 81st Congress, 2nd Session, as a part of the Flood Control Act of 17 May 1950. Work on the project was initiated by the U. S. Army Corps of Engineers (CE) in the spring of 1966 and was finished in March 1973 at a total cost of $466 million (1973). The completed project consists of a concrete gravity dam, a reservoir with a total gross storage capacity of

5,869,000 acre-feet, and a hydropower installation of eight 105-Mw units with five additional 105-Mw units currently under construction. Total length of the reservoir at full pool is 90 miles, 42 of which extend into Canada. The 4,979,000 acre-feet of flood storage provided by the project in combination with the existing levee system now completely controls flooding in the Kootenai Valley downstream from the damsite. During the period 1948-63, floods in the U. S. portion of the valley resulted in damages exceeding $19 million; these damages could have been prevented if Libby Dam had been in operation. In addition, the storage capacity provided by Libby Dam is considered an essential element for protection of the highly developed floodplain of the lower Columbia River and for supply of downstream hydroelectric projects.

3. Several major relocations were required upstream from the dam construction site due to impending inundation. One of these relocations was the Great Northern Railroad* east/west main line. After consideration of several alternatives, an agreement was signed between the Great Northern Railway Company and the CE on 29 January 1966 to relocate the main line between Jennings and Stryker, Montana, following a route parallel to the Fisher River from its confluence with the Kootenai upstream to Wolf Creek (Figure 1). The main line would then parallel Wolf Creek, cross Elk Mountain through the Flathead Tunnel, and continue on to Stryker. Construction of the main line through the narrow Fisher River Valley required extensive channel realignment in order to provide sufficient width to accommodate both the streambed and railroad bed. The modified channel between Jennings upstream to the Fisher's confluence with Wolf Creek constitutes the Section 32 Program existing site.

4. Fisher River rises on the western slopes of the Salish Mountains in Lincoln and Flathead Counties, Montana, and flows to its confluence with the Kootenai River near Jennings (Reference 1). The Fisher drains a watershed of 838 square miles, of which 216 are in the Wolf Creek drainage. Primary land-use activities are timber production and cattle ranching. These activities along with road construction have created erosion problems in some areas.

5. Geological investigations conducted in the Fisher River Basin (Reference 2) indicate that the area is underlain by argillite, quartzite, and carbonate-bearing rocks of the Belt Series (Precambrian). These investigations further show that the basin was invaded by the Cordilleran ice sheet. Melting of this glacier formed a lake that occupied the lower basin. Lacustrine silts were deposited over much of the lake bottom during this period.

6. A soil survey was conducted by the U. S. Department of Agriculture (USDA) in the Fisher River drainage (1970) as part of the preconstruction planning for high-voltage transmissions lines which now pass through the basin (Reference 3). Three major soil types were identified: deep glacial till soils on upland side slopes, shallow rocky

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* The Great Northern Railroad merged with Northern Pacific, SP&S, and Burlington Railroads in 1970 to form the Burlington Northern Railroad.

soils on upland ridges, and deep glaciolacustrine soils on low terraces. The glacial till soils have 1/2 to 1-1/2 ft of unconsolidated loessial silt loam surface layers over 5 to 7 ft of slightly sticky and slightly plastic, weakly consolidated cobbly silt loam till. The shallow rocky soils on upland ridges have 2 to 4 in. of unconsolidated loessial silt loam overlying 6 to 12 in. of weakly consolidated very cobbly silt loam. The deep glaciolacustrine soils consist of 10 ft or more of unconsolidated, poorly graded silts and gravelly silts. The USDA concluded that all of these soils were highly susceptible to erosion.

7. A gaging station was operated on the Fisher River at mile 8.6* (published as Fisher River near Jennings, Mont., Reference 4) from December 1950 through September 1969 (abandoned due to construction) (Figure 2c). The drainage area upstream from this location is 780 square miles. Daily discharges of record were: maximum 6,320 cfs, mean 531 cfs, and minimum 50 cfs. An additional gaging station was established at mile 0.8 (published as Fisher River near Libby, Mont., Reference 4) in 1967 and continues to operate through the present (Figure 2a) (the drainage area upstream from this station is 838 square miles). Daily discharges of record are: maximum 7,280 cfs, mean 522 cfs, and minimum 35 cfs (Table 1). A suspended-sediment sample collection station was established in 1967 at mile 1.0 (published as Fisher River near Libby, Mont.) and was operated through January 1976. Daily suspended-sediment loads for the period of record were: maximum 91,200 tons, mean 266 tons, and minimum 0.2 tons (Table 1). Annual suspended-sediment loads of record were: maximum 347,409 tons, mean 97,090 tons, and minimum 8,353 tons.

8. Fisher River supports significant game fish populations, including cutthroat, brook and rainbow trout, and mountain whitefish. The lower 12.5 miles of the Fisher River was not an active sportfishing reach until 1962 when the U. S. Forest Service built an access road (Reference 5). The proposed Great Northern Line relocation through the Fisher River drainage would eliminate a large number of oxbows, pools, and riffles needed for fish habitat. Impact of the proposed channel changes on fish and wildlife resources was studied by the U. S. Fish and Wildlife Service (USFWS) in 1965 (prior to construction of the project) (Reference 6). Conclusions of this study indicated that in addition to the loss of several thousand feet of fish habitat, channel shortening would increase flow velocities and possibly accelerate streambed erosion. Disturbed areas would create sediment pollution problems for fish in undisturbed downstream areas. Reduced water depths caused by wider channels with steepened gradients would hamper upstream fish migration. The USFWS estimated that important game fish populations now existing in these streams would be damaged to the extent that a reduction of 4,600 average annual fisherman-days would occur.

9. Although the conclusions reached in the USFWS study implied that channel modifications along the Fisher River should be held to a minimum to preserve the fishery habitat, the alignment and grade criteria for the Great Northern Line relocation necessitated major channel changes.

* Based on stream mileage prior to channel relocation.

The cost of preserving the oxbows exceeded the benefits as this plan would require construction of 14 bridges. As an alternative, the USFWS approved placement of "rock groins"* to reduce stream velocities, concentrate low flows, aid in the prevention of soil erosion within the channel changes, elim'nate the need for rock sills for prevention of stream degradation, and minimize adverse effects to unaltered downstream reaches of the river. During the initial years after construction of the changes, USFWS indicated that the groins would be needed to control the stream velocity and provide adequate depths for unrestricted movement of fish. Over a period of years, portions of the rock groins would most likely be dispersed over the channel bottom, destroying the original configuration of the groins. However, by this time, the fishery would probably be reestablished and the scattered large rocks and groin remnants would continue to provide effective habitat for fish and a desired natural-appearing stream condition.

10. The Ariana Creek to Jennings contract represented the initial phase of the construction required to relocate the Great Northern Railroad from Jennings to Stryker (Reference 7). This contract provided for the construction of 11 miles of graded railroad bed, 20 ft wide shoulder to shoulder, spurlines sidings, grade crossings, and necessary drainage structures. The contract also required relocation of various segments of U. S. forest roads, 18 stream channel changes, and the construction of 4 bridges. An invitation to bid was issued on 15 February 1966; bids were opened on 29 March 1966. A total of 12 bids were received ranging from a low of $4,947,191.90 to a high of $7,735,326.00. The low bidder was the R. A. Heintz Company, Portland, Oregon, to whom the contract was awarded. During the course of the project, 17 modifications were processed raising the total contract price to $5,103,505.11.

11. The final plan for the Fisher River channel realignment affected 48 percent of the stream's natural channel from its mouth at the Kootenai River (mile 0.0) to its confluence with Wolf Creek (mile 10.9) (Table 2). As a result of the realignment, the channel was shortened by 4,815 ft, increasing the bed gradient through this reach from 34 to 37 ft/mile. To prevent channel degradation and to mitigate impacts on the fish community, 67 groins were placed through the 16 channel changes (Table 2).

12. Groins were constructed of rock placed over a 12-in.-thick layer of gravel bedding (Figures 3-5). Rock extended to a depth of 2.5 ft below channel grade to prevent undercutting and 2 ft above channel grade to provide fish resting pools and reduce stream velocities (Figures 6 and 7). The highest predicted average velocity in the channel changes was estimated to range from 10 to 14 fps. Rock for groins was sized to remain stable against these velocities with some provision for debris loads (Reference 5). Rock weight ranged from 25 to 1,000 lb with at least 75 percent of the stone weighing from 100 to 1,000 lb, and at least 40 percent weighing more than 400 lb. Quarry spalls less than 25 lb were

* The "rock groins" described in this report are notched sills across the channel bottom to control low flows rather than structures extending into the channel from the streambank to protect the bank from erosion.

not permitted in an amount exceeding 10 percent of each load. In addition, the stone was required to meet the following tests:

Test*		Requirement
(1)	Specific gravity (CRD-C 107)	Not less than 2.60
(2)	Absorption (CRD-C 107)	Not more than 3.0 percent water
(3)	Abrasion (CRD-C 145)	Not more than 40 percent weight loss
(4)	Soundness, 5 cycles sodium sulfate (CRD-C 137)	Not more than 10 percent weight loss
(5)	Petrographic analysis (CRD-C 127)	Materials must be free from cracks, seams, expansive minerals, or other features which would cause accelerated deterioration from exposure to project climatic conditions

* All tests conducted according to Reference 8.

With the above specifications, groin design life was anticipated to be in excess of 15 years. No specifications are available for the gravel bedding material.

13. Groin spacing was set so as to concentrate low flows and to provide a minimum pool depth of 1 ft between groins for unrestricted fish movement (Figure 8). The following formula was used to establish the spacing:

$$\text{Groin spacing} = \frac{\text{Required depth (ft)}}{\text{Channel slope (\%)}}$$

Example: For 1 ft required depth and 0.8 percent slope

$$\text{Groin spacing} = \frac{1}{0.008} = 125 \text{ ft}$$

A groin was placed at the downstream end of all channel changes to minimize the stream velocity before reentering the natural channel. The groins were designed so that during periods of low flow, the water would be concentrated at a weir to provide adequate depth for fish movement. The low-flow weir was located at a position two thirds of the distance across the top of the groin as measured from the railroad embankment to keep the current from being deflected against the embankment (Figures 4, 5, 9).

14. Side-slope riprap protection was provided at locations where the railroad or road embankments might be damaged by stream erosion (Figure 10). Revetment design criteria were based on a 50-year flood frequency established by run-off studies of the Wolf Creek and Fisher River drainage basins. For the design flood in the Fisher River and lower Wolf Creek, the maximum water velocity was estimated not to

exceed 15 fps. The revetment was specified to be 30 in. thick and the toe trenched 3 or 5 ft below the existing ground surface, depending on its proximity to the stream (Figure 4). The revetment was extended 4 ft above the 50-year water-surface profile. Gradation of the riprap was specified to be the same as that used for the groins (paragraph 12). A 12-in.-thick gravel bedding layer was provided beneath revetment where filter protection was required; no information is available regarding the specifications of the bedding material.

15. Restoration of disturbed areas by seeding was required in several areas to minimize stream sediment loads and to stabilize cut slopes (Reference 9). Areas to be seeded were selected by field inspection, giving consideration to soil conditions and ability to sustain a vegetative cover. Fire hazard was a primary concern along the railroad; therefore, seeding of railroad embankments was limited to sections most exposed to public view and areas which would contribute measurably to the sediment load of the stream. Three different seed mixes were used; these were identified as mixes "C," "W," and "G." Mix C, used on railroad embankments because of its fire-resistant nature, consisted of:

	Percent by Weight
Fescue, hard dura	70
Bluegrass, Canada	20
Clover, White Dutch	10

Mix W, used for waste areas, consisted of:

	Percent by Weight
Fescue, meadow	40
Brome, smooth	30
Wheatgrass, streambank	20
Clover, Alsike	10

Mix G, used on slopes where fire hazards were not a problem, consisted of:

	Percent by Weight
Fescue, hard dura	30
Brome, smooth	20
Wheatgrass, streambank	20
Bluegrass, Canada	20
Clover, White Dutch	10

16. A total of 132 acres were seeded; 100 acres were seeded by hydromulching at $330/acre (1969). A wood-fiber mulch was used with

seed, fertilizer, and water to form the slurry. The hydromulching application rate was 1,200 lb/acre including 40 to 50 lb of seed per acre in the slurry for all seed mixes. The remaining 32 acres were seeded by broadcasting with asphaltic emulsified straw mulch. This method was more expensive ($500/acre in 1969) than hydromulching because the seeding and fertilizing had to be done in two operations; however, emulsified straw mulch is a good erosion deterrent while the germination process is under way. The asphaltic emulsion also gathers and contains solar heat needed for germination in this cool, mountainous region. No information is available regarding the application rates that were used for the 32 acres seeded by broadcasting; neither is any specific information available regarding the seeding method selected for a given site.

17. After completion of the project, the State of Montana Department of Fish and Game conducted a Federally funded study (1 July 1969-30 June 1972) to evaluate the impact of the channel realignment on the fish community (Reference 10). This study indicated that the groins installed in the channel changes had been successful in promoting shallow pool development and stabilizing the channel bed, but they had produced considerably more sucker habitat than trout habitat. Further, the report indicated that the channel realignment of Fisher River had adversely affected the aquatic environment by: (a) increasing sediment loads, (b) destroying riparian vegetation, (c) raising water temperatures in denuded channels, (d) shortening the stream length, and (e) producing unsuitable physical habitat for game fish. For these reasons, the report concluded that bridges should be utilized whenever possible as an alternative to channel realignment.

It was

18. In September 1967, NPS conducted an inspection of the completed groins in channel changes ~~2, 11, 12, and 13~~ and prepared a report on the findings ~~(Reference 11).~~ Construction records indicated that 28 groins were in place prior to the spring 1967 runoff. Four of these groins were badly damaged, three to the extent that they were hardly recognizable, and the remaining twenty-four all appeared to have been modified to varying degrees, mostly in the weir sections. Stone weighing less than 200 lb generally appeared to have been moved out of the groin and swept downstream. The groins were considered to be effective in reducing erosion and adequate, but not ideal, in the creation of suitable aquatic conditions. The report further indicated that the ability of the groins to direct water flows had been reduced by the spring runoff and their useful life would probably average less than 10 years. Mr. Bonde, who prepared the report, noted that in many cases the digging action of the water flowing over the groins had created good fish habitat; however, there was concern that these pools would only be temporary features of the stream, unless steps could be taken to place material that could resist peak discharges. Further, Mr. Bonde recommended that the groins should be constructed of stone ranging from 200 to 2,000 lb, with 50 percent of the stone weighing over 1,000 lb. These recommendations were accepted and the remainder of the groins placed in Fisher River under the Ariana Creek to Jennings contract were constructed according to these guidelines. Additional inspections of the groins were

conducted regularly through August 1971 (Figure 11); slides taken during these inspections are on file at the Libby Dam Project Office.

19. At the time of the WES inspection visit, the project reach was stable; no serious channel degradation or aggradation was noted. Although groin rock was scattered downstream at some locations ~~(Figure 12)~~, many of the groins were intact ~~(Figure 13).~~ No riprap blankets placed on side slopes had failed.

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2. Jones, W. M., "Progress Report on Geologic Investigations in the Kootenai-Flathead Area, Northwest Montana," Butte School of Mines, Bulletin 23, 1961, Butte, Mont.

3. U. S. Department of Agriculture, Forest Service, "Erosion Class Designation of Soils, BPA Libby - Loop Power Transmission Line," Unpublished, 1970, Missoula, Mont.

4. U. S. Department of the Interior, Geological Survey, Water Resources Data for Montana (published annually), U. S. Government Printing Office, Washington, D. C.

5. U. S. Army Engineer District, Seattle, "Libby Dam Project, Great Northern Line Change, Fish and Wildlife Facilities in Channel Changes," Supplement to Design Memorandum 5, December 1965, Seattle, Wash.

6. __________, "Libby Dam Project, Fish and Wildlife," Design Memorandum 15, Appendix A, November 1965, Seattle, Wash.

7. U. S. Army Engineer District, Seattle, Libby Residency, "Project History - Kootenai River Montana," April 1979, Libby, Mont.

8. U. S. Army Engineer Waterways Experiment Station, CE, Handbook for Concrete and Cement, with quarterly supplements, Vicksburg, Miss., Aug 1949.

9. U. S. Army Engineer District, Seattle, "Libby Dam Project, Seeding," Design Memorandum 36, December 1969, Seattle, Wash.

10. May, B., "Evaluation of Mitigation Measures in Fisher River, Wolf Creek and Fortine Creek, 1969-1972," July 1972, State of Montana Fish and Game Department, Helena, Mont.

11. Bonde, T. J. H., "Libby Dam Project (Fisher River), Rock Groins," September 1967 (unpublished), U. S. Army Engineer District, Seattle, Libby Dam Project Office, Libby, Mont.

Table 1

Discharge and Suspended-Sediment Load Data for the Station Fisher River Near Libby, Montana*

Water Year	Daily Discharge, cfs			Annual Discharge cfs-days	Daily Suspended-Sediment Load, tons			Annual Suspended-Sediment Load, tons
	Maximum	Mean	Minimum		Maximum	Mean	Minimum	
1968	1,430	426	106	155,828	1,000	68	0.9	24,914
1969	4,230	648	116	236,476	10,000	245	0.6	89,509
1970	2,790	400	80	146,133	2,800	69	0.4	25,198
1971	4,480	732	90	267,142	13,200	291	0.3	106,250
1972	4,820	813	80	297,585	12,200	314	0.4	114,972
1973	1,320	250	62	91,405	1,240	23	0.2	8,353
1974	7,280	804	88	293,532	91,200	952	0.3	347,409
1975	3,480	472	60	172,126	5,910	165	0.3	60,113
1976	3,700	581	114	212,783				
1977	784	169	35	61,818				
1978	2,520	448	45	163,546				

* The gaging station is located at mile 0.8 and the suspended-sediment sample collection station at mile 1.0.

Table 2

Summary of Fisher River Channel Realignment Changes

Channel Change Number*	Approximate Original Channel Length ft	Channel Change Length, ft	Approximate Length of Channel Loss, ft	Number of Groins	Channel Bottom Width ft	Channel Bottom Elevation Upstream**	Channel Bottom Elevation Downstream**	Slope %	Year Completed
17	2900	2475	425	8	100	2131.9	2113.3	0.75	Fall 1967
16	3280	2860	420	9	125	2170.0	2151.0	0.68	Fall 1967
15	880	860	20	0	115	2183.3	2179.4	0.45	Winter 1966
14	600	585	15	0	105	2209.4	2206.0	0.58	Fall 1966
13	960	740	220	3	100	2260.8	2254.6	0.84	Winter 1966
12	3500	3295	205	18	110	2293.5	2268.5	0.76	Winter 1966
11	2080	1445	635	5	110	2331.1	2315.9	1.05	Winter 1966
10	1140	1080	60	3	100	2342.9	2336.5	0.59	Fall 1967
9	1240	995	245	2	100	2359.2	2353.7	0.55	Fall 1967
8	600	535	65	0	100	2368.2	2366.0	0.41	Winter 1966
7	960	955	5	2	100	2380.6	2377.5	0.32	Fall 1967
6	2720	2615	105	8	100	2401.1	2385.7	0.39	Fall 1967
5	760	690	70	0	100	2407.2	2403.0	0.01	Fall 1966
4	2720	1800	902	5	100	2421.9	2410.7	0.62	Fall 1967
3	1460	835	625	2	100	2426.4	2422.2	0.50	Fall 1967
2	1640	860	780	2	115	2442.9	2439.5	0.40	Fall 1966
Total 16	27,440	22,625	4815	67					

* Channel change 1 was on Wolf Creek. Locations of the channel changes on Fisher River are shown in Figure 2, and are listed in this table in a downstream to upstream order. Channel change 14A consisted only of removing bedrock material along part of a 100-ft reach and thus is not listed in this table.

** In feet above mean sea level.

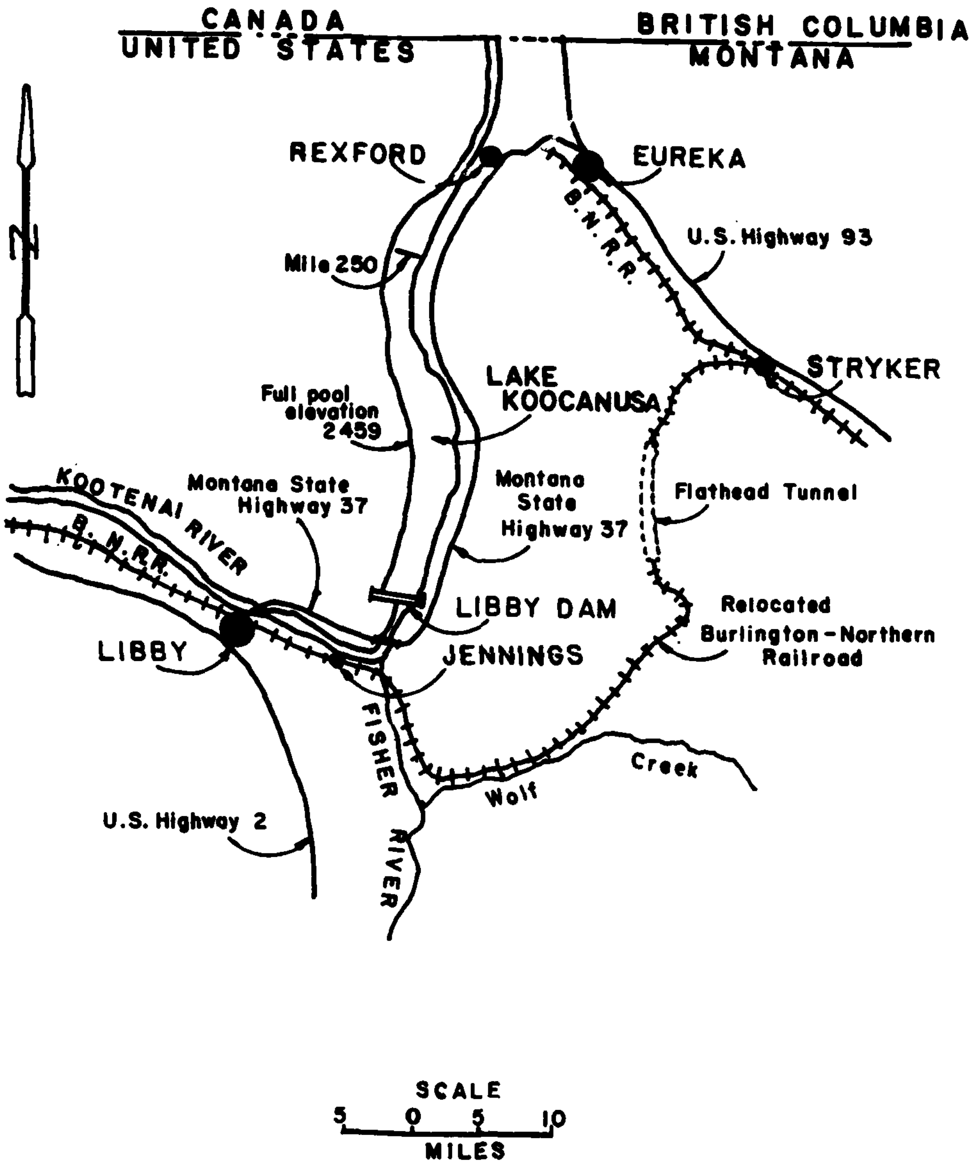

Figure 1. Libby Dam Project and Reservoir location

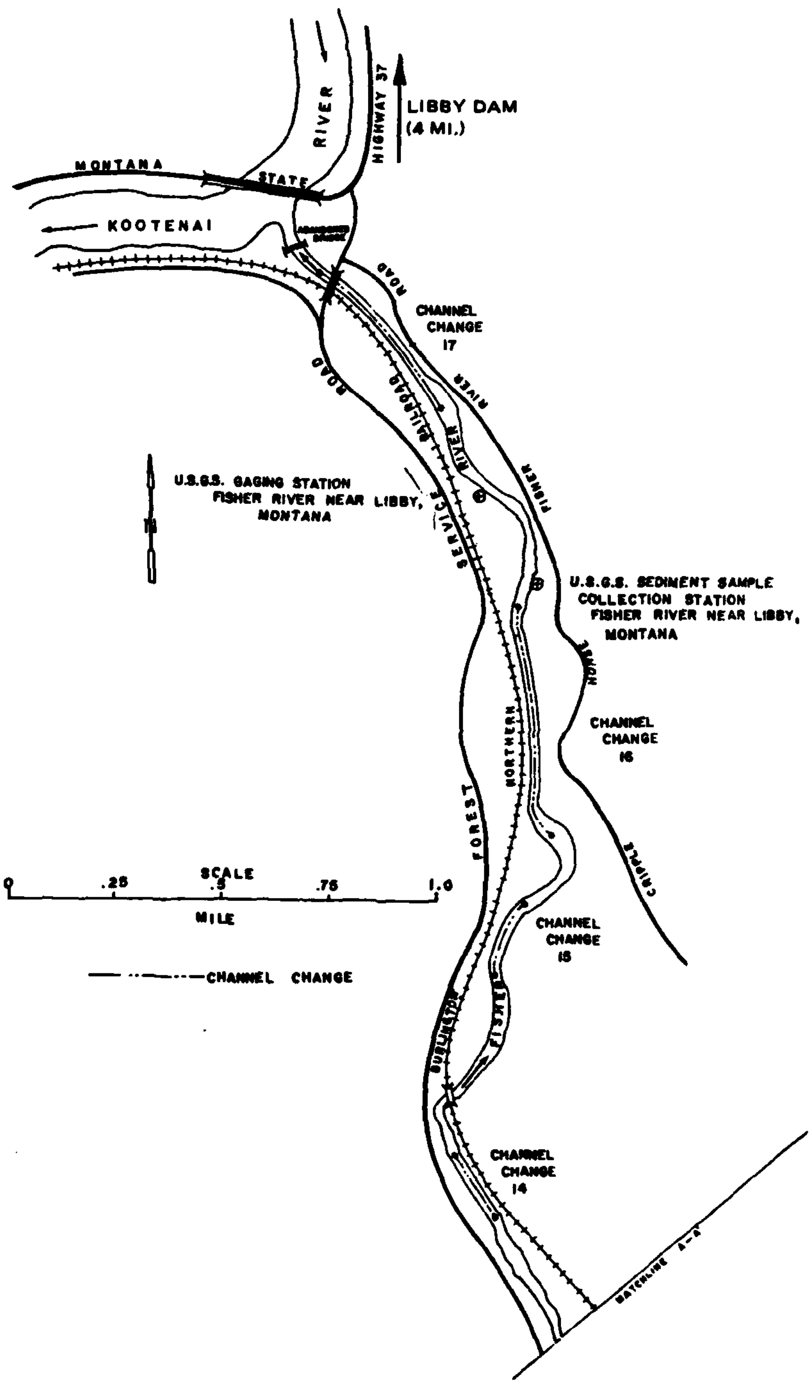

Figure 2a. Fisher River Realignment Project

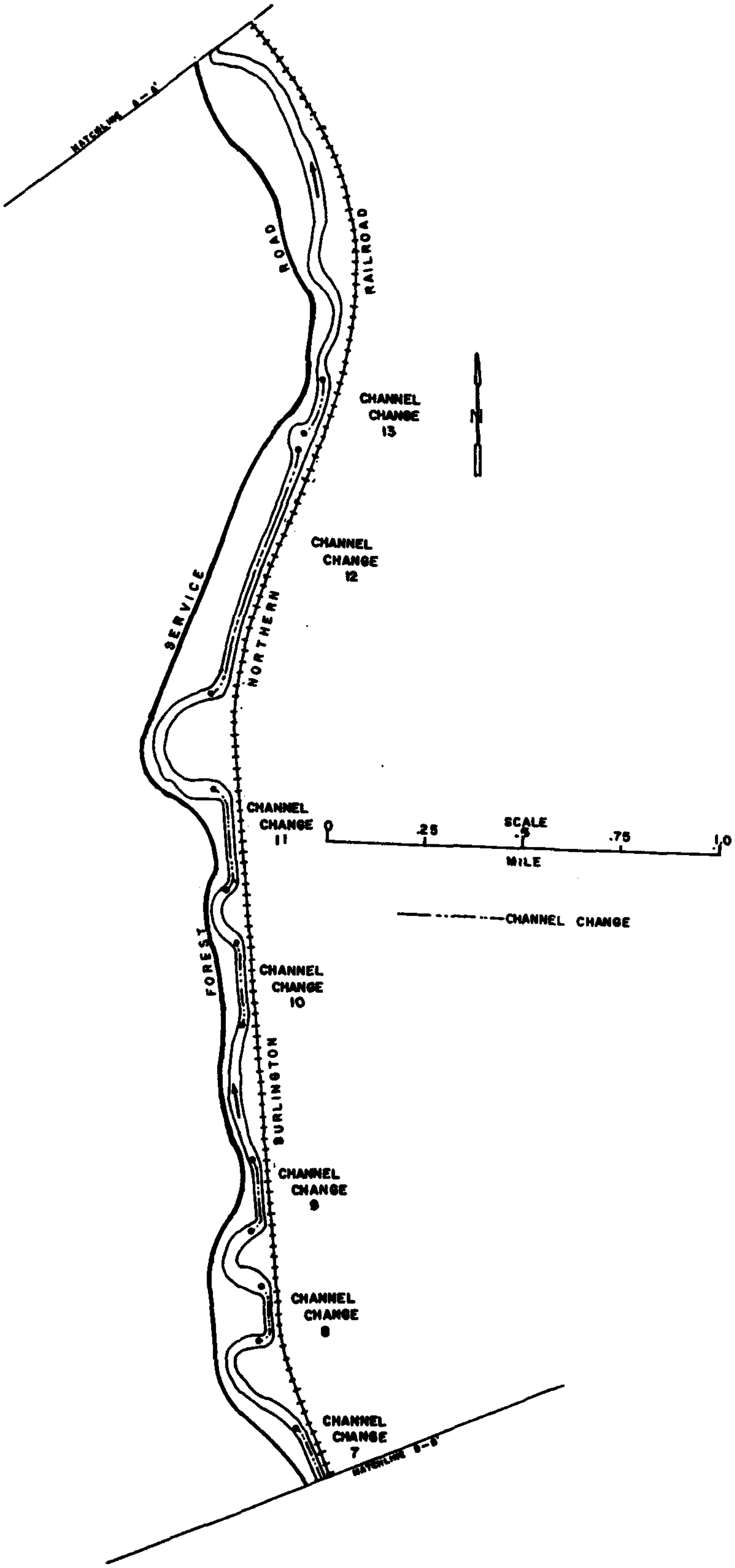

Figure 2b. Fisher River Realignment Project

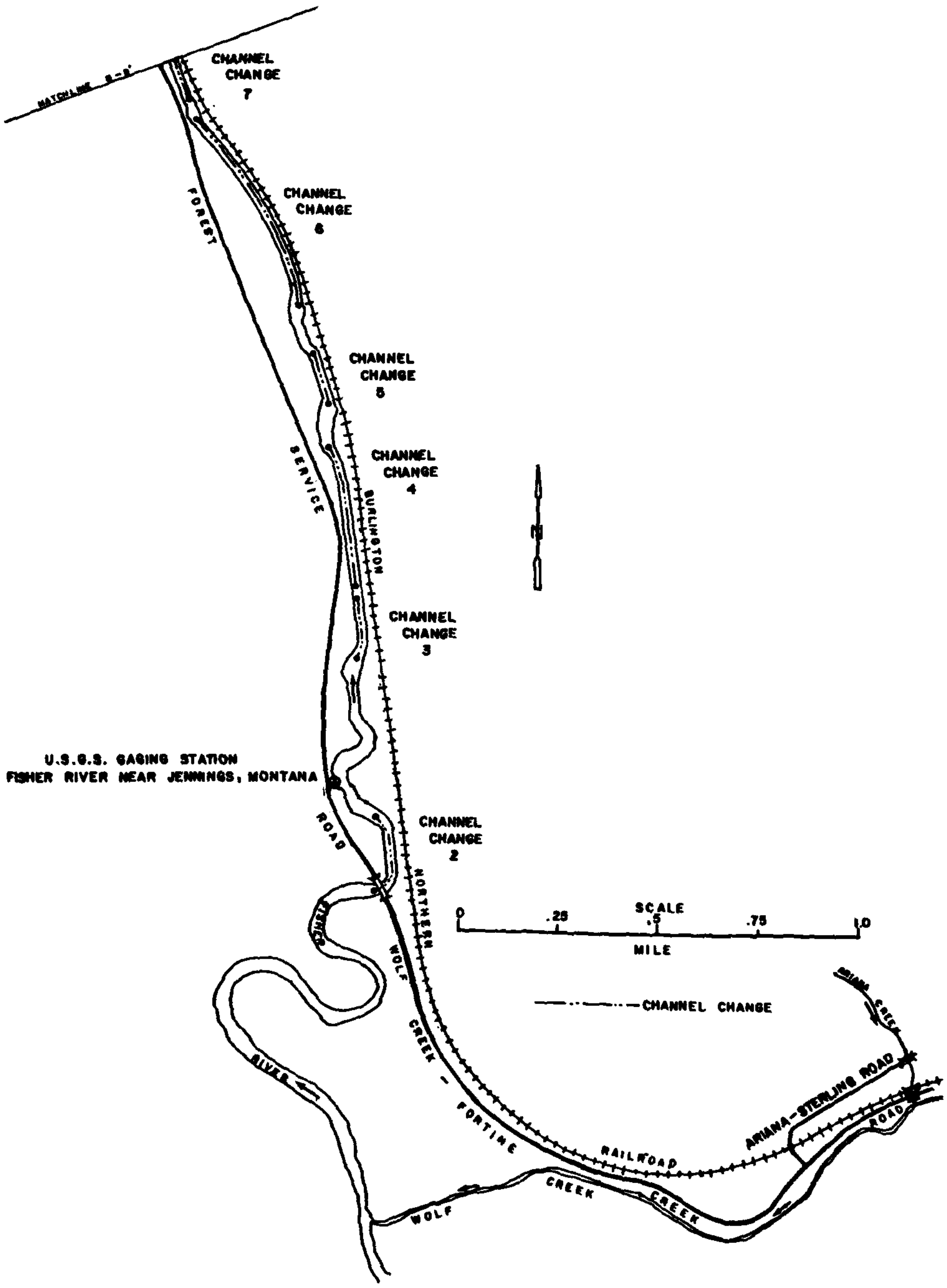

Figure 2c. Fisher River Realignment Project

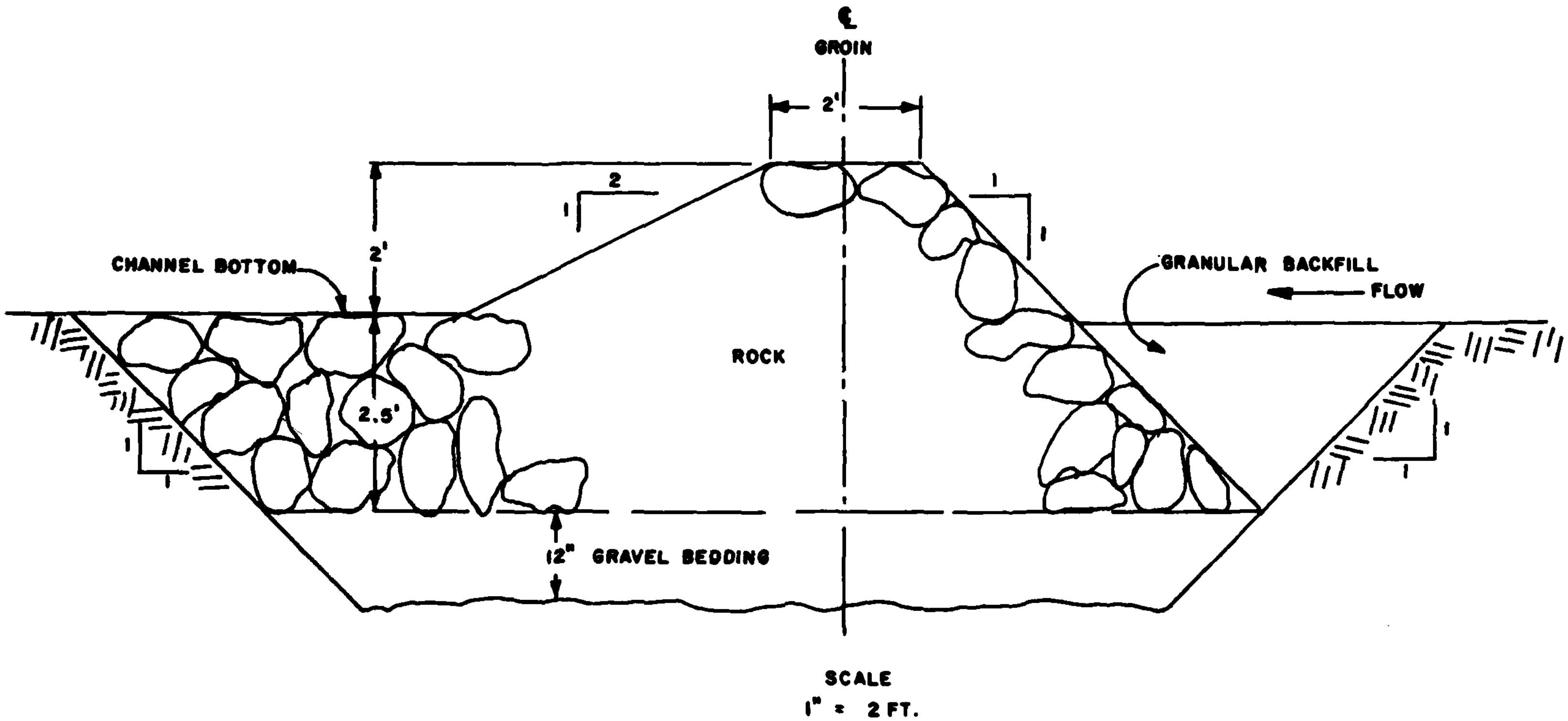

Figure 3. Cross-sectional view of groins (adapted from Great Northern Line Change, Ariana Creek to Jennings, Groins, Drawing E-53-33-81, December 1965, NPS)

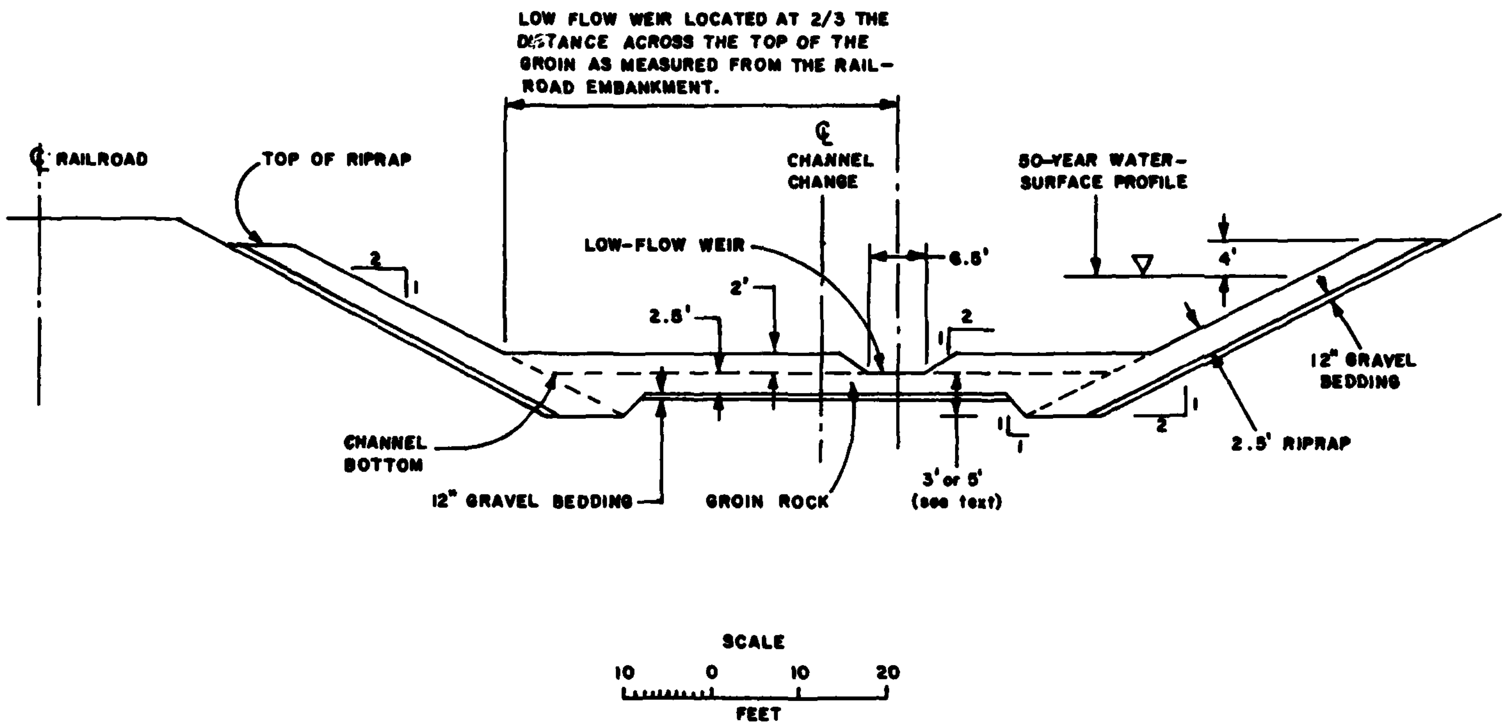

Figure 4. Typical cross-channel view of groin and railroad embankment (adapted from Great Northern Line Change, Ariana Creek to Jennings, Groins, Drawing E-53-33-81, December 1965, NPS)

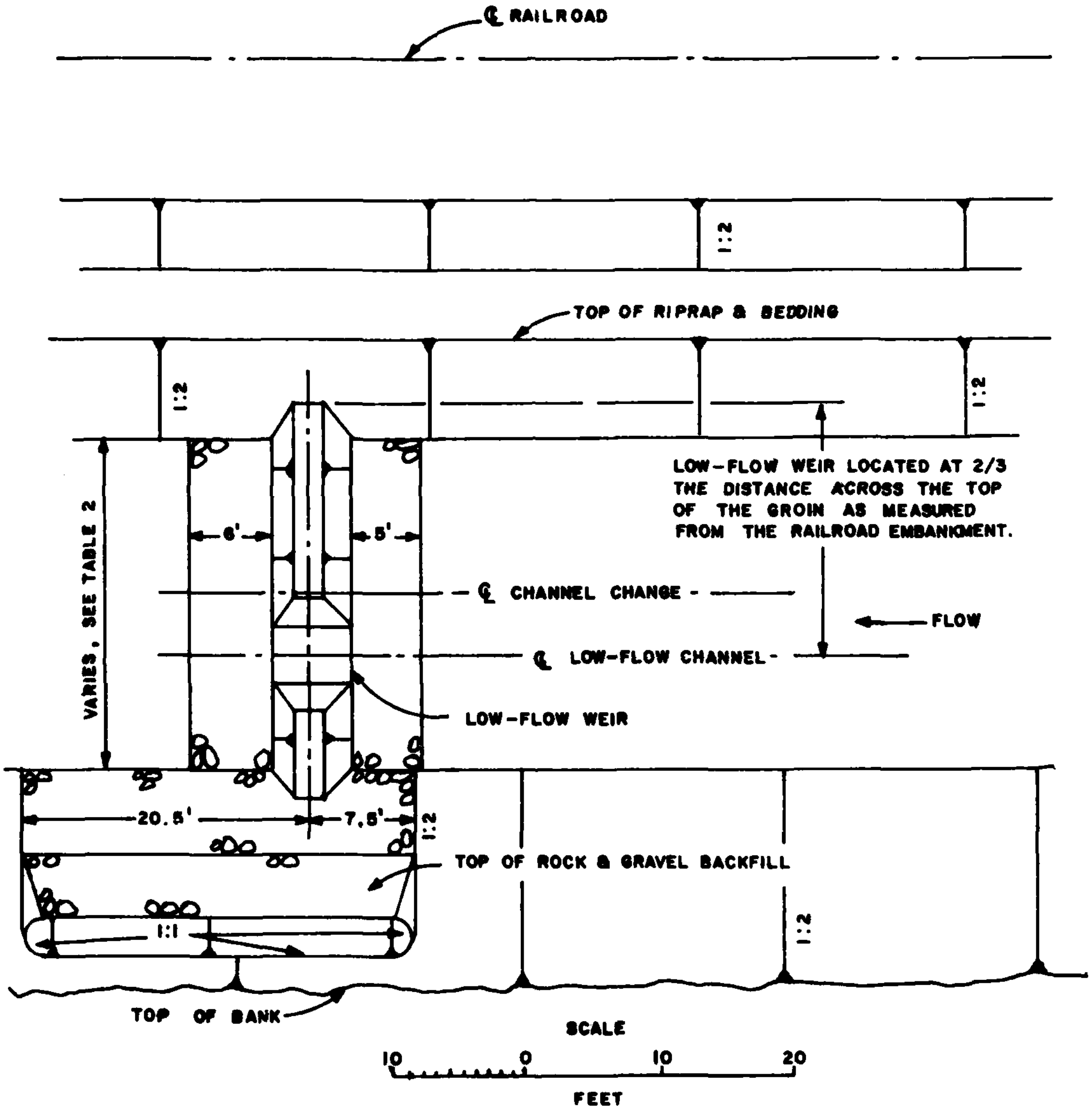

Figure 5. Typical plan view of groin and railroad embankment (adapted from Great Northern Line Change, Ariana Creek to Jennings, Groins, Drawing E-53-33-81, December 1965, NPS

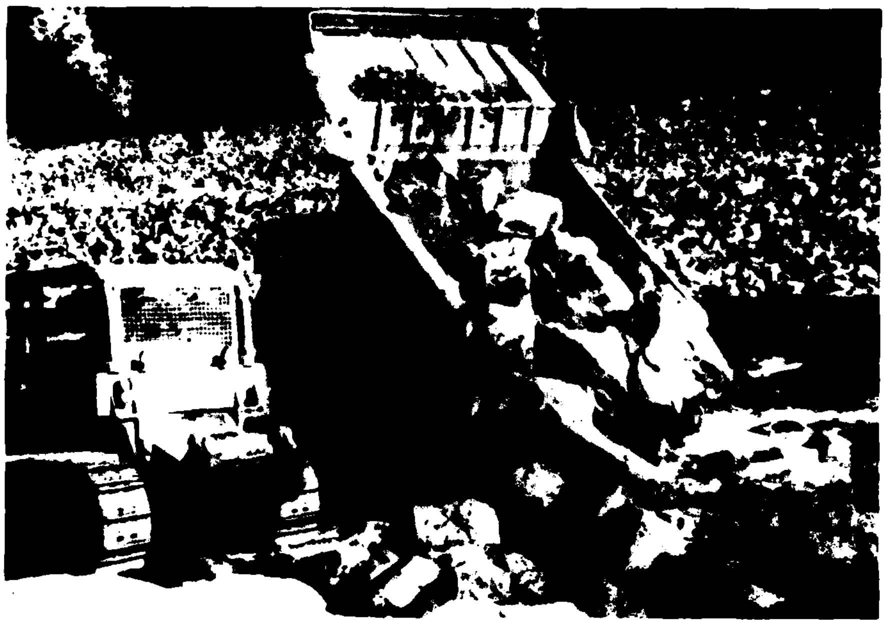

Figure 6. Channel change 10. Construction of groins (26 Oct 67). (Photograph provided by NPS, Libby Dam Project Office)

a. Under construction (24 Aug 67)

b. Completed channel change (1 Sep 67). Measured discharge when photograph was taken was 11 cfs. Note railroad bed under construction at right

Figure 7. Channel change 17. (Photographs provided by NPS, Libby Dam Project Office)

Figure 8. Channel change 11. Aerial view of completed change with groin spacing computed using equation in paragraph 13. (Photograph provided by NPS, Libby Dam Project Office)

Figure 9. Channel change 16. Low-flow weir (25 Jan 68). (Photograph provided by NPS, Libby Dam Project Office)

Figure 10. Channel change 9. Side-slope riprap protection was provided at locations where the railroad or road embankment might be damaged by stream erosion (3 Oct 68). (Photograph provided by NPS, Libby Dam Project Office)

a. Groin was placed in the fall of 1967. This view of the groin on 3 Oct 68 shows the structure to be intact

b. The groin had become dispersed by 20 Aug 71

Figure 11. Channel change 10. (Photographs provided by NPS, Libby Dam Project Office)

a. Condition of groins on 13 Aug 70, three years after placement. (Photograph provided by NPS, Libby Dam Project Office)

b. The groins were still recognizable on the date of the WES inspection visit (8 Aug 79); however, the rock was widely scattered

Figure 12. Channel change 17 viewed upstream from bridge

Figure 13. Channel change 9 on the date of the WES inspection visit (8 Aug 79). Many of the groins were still intact